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Review Article

Cultural practices in European riverine floodplains: formation, typology, co-decline of biocultural diversity, and emerging drivers of conservation and sustainable management

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Abstract

Floodplain wetlands in riverine environments are characterized by rhythmic hydrological changes, which re-structure physical habitat, change between aquatic and dry life conditions, reset successions, and facilitate the respective food chains and/or migration/drift of nutrients and organisms. Since the earliest days of humankind, these floodplains were sought-after places for humans to settle, use natural resources directly or indirectly, to learn from nature. and even to venerate nature in spiritual relationships. The fast industrial and commercial developments of the past centuries have caused a decrease in the valuation of wetlands by humans, going along with the cutting-off of the natural hydrological regime by dikes and dams and their large-scale transformation into permanent dry land. This paper delivers a review on (i) Driving forces that form biocultural diversity in river floodplains, (ii) Typology of cultural activities in river floodplains, (iii) Today's co-decline/extinction of biocultural diversity in river floodplains, and (iv) Cultural practices as inspiration for future conservation and sustainable development in Europe. Rather than presenting cultural practices in the form of a "Red list", we want to highlight that they are actually a tool to rediscover, evolve, or create new cultural linkages with rivers and their floodplains and to help to take action to better respect, protect, restore, or to newly create these floodplains.

Highlights

- Cultural practices can be studied in a similar way to more-than-human species traits, including their cultural activities.
- Biological and cultural diversity in floodplains is threatened by similar drivers.
- Cultural diversity can deliver important incentives for floodplain management.

Key words: Biocultural diversity, floodplains, heritage, management

Environmental driving forces for biocultural diversity in riverine floodplain wetlands in Europe

Rivers and riverscapes (including river corridors, adjacent valleys, and their spatial-temporal dimensions, Torgersen et al. 2022), provide essential material resources for both human and more-than-human life, such as habitable land, fertile soils, water, construction materials, and animal protein. The pulsing hydrodynamics of river-floodplain systems—characterized by wet-dry cycles—are key environmental drivers of biological and cultural diversity in riverine areas (Wantzen et al. 2016).

River floodplains are hotspots of biodiversity (see Kaden et al. 2026), as described by the Flood Pulse Concept and its updates (Junk et al. 1989; Junk and Wantzen 2004, 2007). The flood-drought cycles create regular "windows of opportunity"—periods of abundant resources—and "windows of susceptibility," when survival risks increase. Organisms with life cycles synchronized to these hydrological phases gain a selective advantage, using the "flood pulse advantage" (Bayley 1991) when flooding coincides with the productive vegetation period. Inter-annual variability in flood patterns further promotes coexistence of diverse life-history strategies, leading to "sequential biodiversity" and exceptional biological diversity in floodplain habitats (Wantzen 2022). Therefore, river floodplains foster significant cultural diversity, both tangible and intangible.

In the context of this paper, culture is understood as a learned behavior expressed in patterns that are handed over between generations or social groups (Johnston et al. 2012, and see below). There is increasing evidence that collective behavior among animal groups can also be considered as "culture" (Brakes et al. 2019). Like biological adaptations, cultural adaptations to the natural flow regime are composed by use strategies (windows of opportunity, e.g., to profit from seasonally occurring resources such as migratory fish) and risk avoidance strategies to "windows of susceptibility" (to cope with adverse life conditions, e.g. cattle transhumance, migration, or adapted architecture to cope with floods, Wantzen et al. 2016). Worldwide, there are many examples for adaptations to these alternating types of "windows" created by hydrological rhythms but humankind has also brought upon immense cultural activities to counteract the natural dynamics by damming, dyking and deviation of rivers, many of which have had a negative effect on ecosystem functioning and biocultural diversities (see Wantzen 2023 for a global revision of biocultural adaptations, Belletti et al. 2021 and Grill et al. 2019 for reviews on damming and fragmentation of rivers and Sexton et al. 2024 for navigation impacts). Flood-adaptive strategies also have strongly influenced urbanism and built heritage (Larsen and Logan 2018; Hein 2020), however, due to the context of this book (with a focus on floodplains in open landscapes), these are not dealt with in detail here.

Archaeological evidence indicates human utilization of riverine resources dating back 500,000 years (Joordens et al. 2015), with floodplains serving as primary settlement locations and rivers facilitating cultural dispersal (Parfitt et al. 2005). At the local scale, human societies have historically adapted to flood dynamic environments through specialized resource-use and risk-avoidance practices, producing cultural practices such as the precisely timed spring tree-harvesting for flood-adapted stilt-houses around Lake Constance (dating back 7000 years), the seasonal production of Roman fermented fish sauce ("*garum*") in the Loire floodplains, and fishing traditions associated with migratory fish species like the allis shad (*Alosa alosa*, "Mai-Fisch", alluding to the fish migrations occurring in May) in Germany or

monastic fishing rules on the Rhine (Wantzen et al. 2023 a, 2023b). Additionally, intangible cultural heritage has emerged through spiritual and ritual practices, including harvest or fishery festivals on the Seine (Lestel et al. 2023) and the Rhine rivers, and rituals venerating or appeasing river-associated deities in response to flooding events, exemplified by Celtic cults dedicated to the deity "*Rhenos*" along the Rhine, or beliefs regarding a mythical worm-like creature causing bank erosion in the Dordogne catchment (Michau et al. 2022; Wantzen et al. 2023b). Thus, the transversal connectivity between the river mainstem and the floodplain water bodies fosters the diversification of biological and cultural diversity.

Connectivity between the main river channel and adjacent floodplains promotes both upstream and downstream migration of biota and their cultures. At the river basin scale, biological and cultural diversities in floodplains exhibit comparable patterns of speciation and dispersal. For example, research in Swiss alpine drainage basins has demonstrated that diversity patterns of aquatic insects in river systems are influenced by river network structures (Altermatt et al. 2013). The Eurasian beaver (*Castor fiber*) has recolonized Central European floodplains following reintroduction programs, being directly facilitated by river corridor connectivity (Halley et al. 2021). Similarly, cultural elements (e.g., linguistic expressions) migrated up- and downstream along the Rhine via towboats and steamboats, or downstream rafting of logs from the Black Forest for city construction in the Netherlands (Wantzen et al. 2023b).

From a temporal perspective, human-river relationships have evolved from ancient adaptive and respectful approaches toward floodplain dynamics to modern anthropocentric interventions (Johnston et al. 2012; Wantzen et al. 2016; Macklin and Lewin 2020; Wantzen 2022). Consideration for ecological factors (and environmental risks) dramatically diminished during the industrialization period of the 19th century and the post-World War II era. Increased reliance on engineering solutions prompted extensive development in high-risk flood zones (Schindler et al. 2016; Brown et al. 2018), the "domestication" of riverscapes (Tockner et al. 2011), and substantial reductions of natural floodplain areas—e.g., an estimated 80–90% loss in Germany (Koenzen et al. 2024)—paradoxically exacerbating flood risks (Schober et al. 2020). In recent years, however, the combination of climate change-induced flooding events, advanced risk assessment methodologies (Hegger and Dieperink 2014), and economic pressures from insurers (Zurich Insurance 2013) has catalysed European-scale policy reforms. Notably, the European Flood Directive (Priest et al. 2016) prohibits urbanisation in flood-prone areas (Kundzewicz et al. 2010), and efforts have increasingly focused on restoring/re-naturalising floodplains, representing a tentative return towards more sustainable human-river relationships (Fig. 1).

This paper analyses human social and cultural practices in riverine floodplain wetlands, structured according to their hydrological, topographical, and climatic settings—factors that determine the extent of floodable areas, the periodicity of hydrological pulses, and the alignment of flooding phases with vegetative cycles (Tockner and Stanford 2002; Junk and Wantzen 2004). It offers the first systematic catalogue of such practices in the European context, where cultural ties to biological species or ecosystems—often rooted in animistic traditions like shamanism—are now largely absent. It offers a typology of cultural practices directly or indirectly linked to the pulsing hydrology of rivers, integrating a historical perspective and revised methodological approach based on a system devised under the auspices of the Ramsar Convention on Wetlands. In the following, we examine

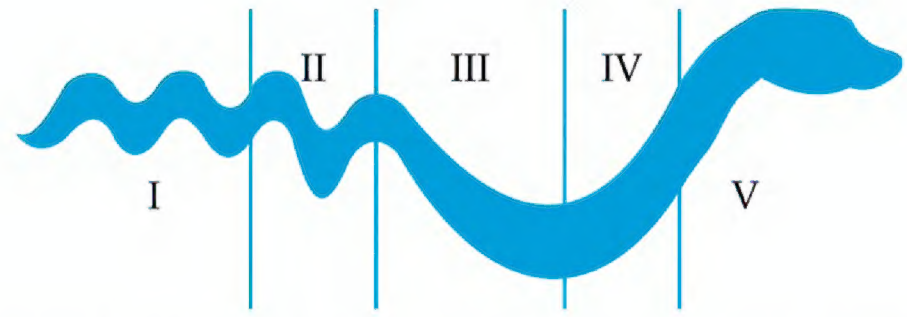

Figure 1. The "watersnake" model of developmental phases of biocultural diversity in rivers. I: River dynamics control all human options to settle in river floodplains and use their natural resources (early civilizations). II: Local diking, damming and overuse of riverine resources. III: Industrial and postindustrial phases. Coalescing and interacting multiple stressors (river engineering, water pollution and abstraction) strongly degrade biocultural diversities. IV: Postindustrial phases. Governments and participatory processes collaborate to restore environmental quality, revitalize and transform sustainable cultural elements and combine them with innovative, nature-based, and technological solutions. V: An ideal future: Harmony between human nature and river culture. Source: (Wantzen 2023, CC-BY-SA).

global and local trends that modify, threaten, or eliminate these practices, highlighting how biological and cultural diversities often follow similar patterns of evolution and decline. Analogous to the concurrent, co-located extinction of species and linguistic diversity in terrestrial ecosystems, cultural diversity in floodplains is eroding alongside biodiversity. Nonetheless, the cultural connectivity of rivers—expressed through senses of place and time, as well as preserved/newly developed cultural uses—can serve as a powerful driver for restoration, conservation, and the development of sustainable management strategies. Accordingly, the final part explores the motivations and outcomes of culture-led initiatives in the context of climate change and the bio-cultural diversity crisis. Rather than proposing a "red list" of endangered cultural diversity, this paper aims to present constructive examples of culturally grounded actions in European floodplain wetlands that can help to contribute to future sustainable development and shed light on the conservation of river-floodplain systems worldwide.

Cultural activities in the context of ecosystems are often considered as "Cultural ecosystem services" (see Jähnig et al. 2022 and articles by Stammel et al. this SI for riverine floodplains and Ibanez et al, this SI for coastal wetlands). Suggestions for Nature-based Solutions to improve or support these services exist especially in the urban context, in the form of Urban Human-River-Encounter Sites (Zingraff-Hamed et al. 2021), stream daylighting (Wantzen et al. 2022a), urban restoration (Wantzen et al. 2022b), or multiple use wetlands (Alikhani et al. 2021). While the methods to assess values of these services are quite advanced when it comes to non-cultural services (Hornung et al. 2019), the thematical diversity and (often) the non-tangibility of cultural practices make their valuation difficult (Jähnig et al. 2022). By delivering a typology, this article aims at providing a first basis for this evaluation.

Typology of cultural practices in river floodplains

Riverscapes function as repositories of culture—understood as the distinctive spiritual, material, intellectual, and emotional characteristics that define societies. These cultural elements exist in both tangible and intangible forms, transmitted across generations and social groups. They represent accumulated knowledge from past civilizations while continuously evolving through ongoing practices (Johnston et al. 2012).

Studies have documented diverse cultural elements related to rivers' natural flow regimes, manifested through multiple dimensions: resource utilization (e.g., water, fisheries, Wantzen et al. 2016); spatial adaptations (e.g., architecture and landscape design); temporal patterns (e.g., cultural activities synchronized with hydrological cycles, Jackson et al. 2022; Wantzen 2022); place attachment and identity formation (Anderson et al. 2019; Wooltorton et al. 2022); art and aesthetics (Lestel et al. 2023, Fig. 2); religious/ spiritual linkages (Johnston et al. 2012); and community stewardship through kinship relationships (Wilson and Inkster 2018).

To systematically analyze the complex interactions between nature and culture, in a framework for wetland cultural practices developed in the context of the Ramsar Convention on Wetlands, Papayannis and Pritchard (2008) provided a structured taxonomy comprising four categories: 1) Habitation and transport practices; 2) Direct use forms; 3) Indirect use forms; 4) Non-material relationships (scientific, spiritual, health, and well-being). Taking into account the full range of documented river-related cultural practices, we employ this framework while expanding the fourth category (non-material relationships) to more effectively analyze how riverscapes evolve into cultural landscapes through specific human–river interactions across historical and contemporary contexts. A fifth category on human wellbeing (physical and psychological) was also added. This expansion better accommodates the nuanced spectrum of cultural expressions that extend beyond the more detailed treatment of direct and indirect use forms in the original framework.

Although debates persist regarding the conceptualization of cultural landscapes in riverine contexts—particularly over the extent to which these landscapes result from deliberate planning versus adaptive responses—substantial evidence indicates that socio-ecological dynamics have profoundly shaped these environments over time. To empirically illustrate these complex dynamics, we present historical/contemporary examples from European riverine floodplains, highlighting the temporal continuity and spatial diversity of riparian cultural practices (Table 1).

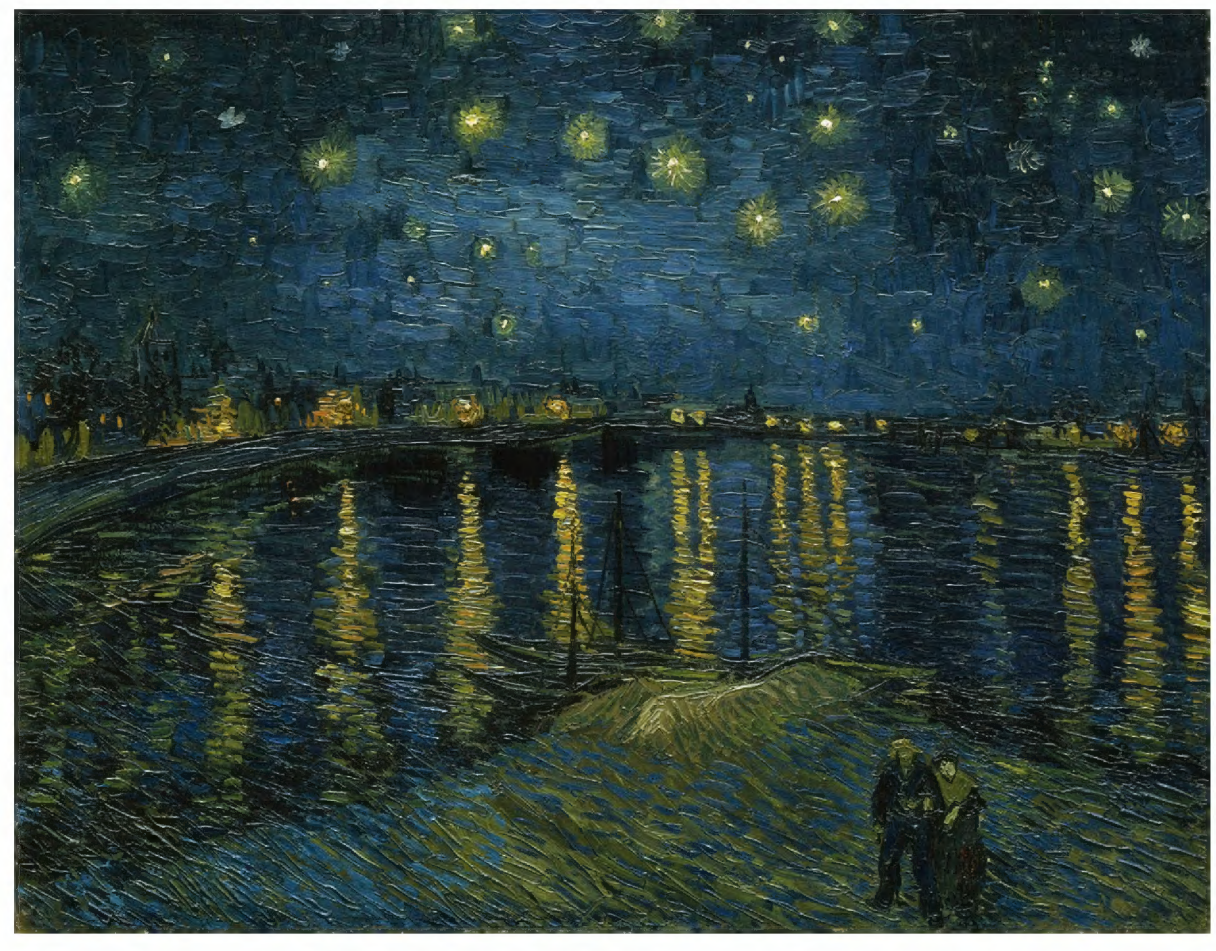

Figure 2. Vincent van Gogh, Starry Night Over the Rhône, 1888, Musée d'Orsay, Paris, France. Source: Wikimedia Commons (public domain).

Table 1. Comparison of categories of human activities in river wetlands (drawing on the Ramsar guidance categories in Papayannis and Pritchard 2008). Asterisks* indicate additional categories developed for the context with river floodplains. Examples were mostly taken from the chapters on Loire (Wantzen et al. 2023a), Rhine (Wantzen et al. 2023a), Seine (Lestel et al. 2023), Dordogne (Michau et al. 2023), Ebro (Mariano et al. 2023), Venice (Eulisse et al. 2023) in Wantzen (2023); other references are added specifically.

Ramsar guidance categories, and new riverine categories	Examples of cultural practices from European riverine floodplains
1. Habitation and transport	
1.1 Cultural landscapes	Palladian Landscape (Venice). Viticulture in the Rhine, Moselle, Danube, Loire, Rhône, Gironde (Bordeaux), Dordogne rivers
1.2 Cultural heritage sites	Loire Valley (including the châteaux), Douro, or Middle Rhine UNESCO World Heritage sites
1.3 Settlements and structures	Dutch mires drainage, peat extraction and land reclamation, canal systems and urban agglomeration (Amsterdam)
1.3.1 Ancient sites and structures (up to 1599 CE)	City foundations at river crossings, e.g., Lyon (at the confluence of the Saône and Rhône rivers), Koblenz (whose name derives from the Latin *confluentes*), or at intersections between river corridors and terrestrial trade routes, e.g., Paris. (Flood adaptive) Neolithic pile dwellings around the Circum-Alpine lakes and their outlets.
1.3.2 Traditional and modern settlements and structures	Traditional: In 19th-century Europe, public/private bath facilities—often gender-segregated—were developed on rivers. E.g., in Lyon, the city council operated the "Bains de la Tête d'Or" on the Rhône River (1879–1899) to improve public hygiene (Terret 1994).Modern: Floating neighborhoods in Amsterdam and Rotterdam, the Netherlands
1.4 Wetland archaeology	Roman ships on the river Rhine at Mainz
1.5 Infrastructure	
1.5.1 Terrestrial transportation networks	River trails, railways, towpaths for boats ("Leinpfade, Treidelwege") on the Rhine
1.5.2 Water management facilities and networks	Navigation canals, e.g., canals connecting the Danube-Main-Rhine, Rhine-Rhône
2. Primary use of wetland resources	
2.1 Agriculture	
2.1.1. Rice cultivation	Rice farming tradition in the Ebro Delta (Spain) (Genua-Olmedo et al. 2016)
2.1.2 Other wetland related agriculture	In the Netherlands in the 11th–12th century, large-scale drainage of peatlands for agriculture
2.2 Stock-breeding	Cattle grazing on floodplain meadows in the Loire River (Yousry et al. 2022)
2.3 Fishing and aquaculture	
2.3.1 Artisanal fisheries	Monasterial fishing rights dating back to the 10th century in the Rhine River
2.3.2 Commercial fisheries	Declined extensively in Western Europe
2.3.3 Extensive aquaculture practice	Carp pond culture (but mostly outside the floodplains, e.g., Parc naturel régional de la Brenne, France)
[2.3.4 Intensive aquaculture facilities]	Fishery cooperatives operate in oxbow lakes in floodplains in Hungary (Borics et al. 2016; Löki et al. 2021)
2.3.5 Sports fishing	Common all across Europe (Arlinghaus et al. 2007)
2.4 Management of forest wetland types	
2.4.1 Wood products	Poplar plantations for energy/paper production, Riverside willows grown for riverbank stabilization and propagated for ornamental planting and crafts.
2.4.2 Non-wood forest products	Harvesting of Wood Garlic (*Allium ursinum*) and other herbs (all over Europe), wild asparagus (*Asparagus acutifolius*, *Ornithogalum pyrenaicum*) in France, Spain, small-scale watercress (*Nasturtium officinale*) harvesting (chalk streams, England, Germany)
2.5 Hunting	
2.5.1 Subsistence hunting	Rare in Europe
2.5.2 Sports hunting	Common across Europe
2.6 Salt extraction	
2.6.1 Artisanal/traditional salinas	Mostly in marine coastal areas (France, Spain), "Gradierwerke" (former salt concentration constructions, today used for local climate) e.g., at the Nahe river (tributary to the Rhine)
2.6.2 Industrial facilities	France's nuclear power plants (e.g., Belleville, Chinon, Saint-Laurent, Bugey, and Tricastin) are located near major rivers (e.g., the Loire, Garonne, and Rhône) to ensure an adequate water supply and efficient cooling.
[2.7 Mining and quarrying]	
[2.7.1 Sand and gravel extraction]	Common across Europe, especially after WWII, e.g., Loire River: riverbed incision of avg. 1.5 m. Today, a sediments augmentation to compensate sediment losses in the hydropower/navigation dams) is necessary, e.g. in the Upper Rhine

Ramsar guidance categories, and new riverine categories	Examples of cultural practices from European riverine floodplains
[2.7.2 Gold mining]	Low importance (e.g., during gravel extraction on the Rhine)
[2.7.3 Other mineral extraction]	N/A
2.8 Water use	
2.8.1 Irrigation	Common across Europe, increasingly causing problems for wetland species due to water use conflicts, e.g., Upper Rhine, Cota Doñana, Spain (Green et al. 2024)
2.8.2 Domestic use	Common across Europe, e.g., drinking water supply in Paris from Seine and the Marne rivers
2.8.3 Water transfer infrastructure	Canals connecting rivers for navigation purposes, common across Europe
2.8.4 Industrial use (energy production)	Common across Europe
2.8.5 Other water uses (water mills, sawmills etc.)	Common across Europe; conserving historical built heritage increasingly conflicts with river connectivity restoration (e.g., Sélune River, France, Drapier et al. 2024)
2.9 Use of other wetland natural resources	
2.9.1 Biomass extraction	Biomass production in floodplains along the Rhine River (the Netherlands) (Koopman et al. 2018)
2.9.2 Sustainable use of medicinal plants	Herbal medicine in the Balaton Lake Region, Hungary, preserved as an intangible cultural heritage (Nemethy et al. 2020)
3. Secondary use of wetland resources	
3.1 Food processing	
3.1.1 Traditional methods of food preservation	Birch and maple sap harvesting and fermentation in Northern/ Eastern Europe (Svanberg et al. 2012)
3.1.2 Culinary heritage	Common across Europe (e.g., fish and mussel recipes)
3.2 Craftsmanship	
3.2.1 Artefacts	
3.2.1.a Artefacts of ancient origin (up to 1599)	Neolithic, Celtic and Germanic findings across Europe
3.2.1.b Traditional and modern artefacts	Traditional fishing tools, boats, river-related equipment across Europe (Rhine, Seine, Loire)
3.2.2 Handicrafts and tools	
3.2.2.a Handicrafts and tools of ancient origin (up to 1599)	Fish traps dating to the early Anglo-Saxon period (5th to 7th centuries) in the inter-tidal zone of the River Thames in London (Cohen 2011)
3.2.2.b Traditional and modern handicrafts and tools	Canal art and boat painting emerged in 19th century in Britain as a cultural practice among waterway communities, known for its “Roses & Castles” imagery, bold patterns, and vibrant colors (Wincott et al. 2019)
3.2.3 Transportation means (boats etc.)	
3.2.3.a Ancient transportation means (up to 1599)	Loire ship architecture, dating back to Viking invasions ca. 900 CE, traditional Rhine rafts for wood transport up to 300 m long
3.2.3.b Traditional and modern transportation means	Shipping lines, e.g. Köln-Düsseldorfer or Viking lines on the Rhine
3.3 Traditional building construction	
3.3.1 Dwellings	Historical human settlement was often located where terrestrial and fluvial transport routes intersected or at river confluences, which provided defensive advantages.
3.3.2 Utilitarian buildings	Wooden store houses and port cranes along the Rhine River
3.3.3 Public buildings	Public river bathing houses, many remain in Swiss. E.g., Frauenbadi built in 1837 as a ‘bathing house for women’ in the Limmat River in Zurich (Cao et al. 2025a)
3.4 Wetland-based traditional marketing	To our knowledge, not very common in Europe.
3.5 Tourism – eco-tourism and cultural tourism	Common across Europe
3.6 Leisure and sports	
3.6.1 Nature appreciation	Common across Europe, especially bird watching, e.g., BirdLife International (NGO)
3.6.2 Hiking and mountain climbing	Common across Europe
3.6.3 Rafting and kayaking	Common across Europe
3.6.4 Sailing and boating	Common across Europe
3.6.5 Diving	Common in gravel pit lakes
3.6.6 Speleology	Mostly in karstic areas, e.g. in the Rhine/Danube karst in the Black Forest (Behrmann-Godel et al. 2017)
3.7 Social practices and methods	
*3.7.1 Daily interaction with the river (daily use, riverbanks as social encounter sites)	Historical bathing, laundry practices
3.8 Festivals, celebrations and events	Fish festivals e.g., Wormser Backfischfest (the great festival on the Rhine)

Ramsar guidance categories, and new riverine categories	Examples of cultural practices from European riverine floodplains
*3.9 Dispersal of cultural forms	"Rhenish Humanism", dispersal of humanistic thoughts during the Rhine travels by Erasmus of Rotterdam
4. Knowledge, belief systems and social practices	
4.1 Scientific research and education	Common across Europe
4.2 Traditional knowledge	
4.2.1 Oral traditions and expressions	Common across Europe, e.g., the Loreley legend of a beautiful woman distracting boatmen, resulting in shipwrecking (in reality, turmoil resulting from the specific hydrology at the Middle Rhine)
4.2.2 Languages, dialects and special terms	River valleys serving as cradles and conservatories for local expressions, specific idiolect of fishers and navigators.
4.2.3 Gender, age and social class-related roles	Throughout the medieval and early modern periods, the rise of monotheistic religions centered on God the Father feminized water as seductive and dangerous. European rivers and lakes were often believed to lure people to their deaths (Strang 2023).
4.2.4 Practice of traditional medicine	Collection, cultivation and processing of medical plants, herbs and spices in the Balaton Lake Region, Hungary (Nemethy et al. 2020)
4.3 Spirituality and belief systems	
*4.3.1 Symbol for purity	The Rhine River symbolizes Siegfried and embodies the purity of the German soul—alongside loyalty, heroic knighthood, and a fearless embrace of destiny.
*4.3.2 Respect for natural forces	River floods often interpreted as "wrath of the god(s)".
*4.3.3 Gratitude for fertility	Danubia, the goddess of the Danube River, is believed to be a source of fertility (Roucek 1946). Deification of the Seine (*Sequana*).
*4.3.3 Symbol of Life Cycle	The name of the River Thames (London) comes from a Brythonic word meaning "dark" and was Latinised as Tamesis. It is primarily associated with the deity Old Father Thames, who symbolises abundance and renewal (Higgins 2022).
4.4 Artistic expression	
*4.4.1 Aesthetics	Vincent van Gogh "Starry Night Over the Rhône" (1888) (see fig. 2)
*4.4.2 Rhythm and music	Robert Schumann "Rhine Symphony"Bedřich Smetana "The Moldau"
*4.5 Philosophy: permanent change and eternity	Heraclitus' saying "No man ever steps in the same river twice," inspired by Greek rivers, shaped European thought on change and permanence across cultures.
*4.6 Inspiration to new ideas, arts, concepts	Rhine romanticism
*5. Human wellbeing (physical and psychological)	The British physician, Sir John Floyer, advocated the therapeutic benefits of cold-water (river) bathing (Sir John Floyer (1649–1734) 1943).
*5.1 Local identity (sense of place)	Strong impact on placemaking and sense of place (e.g., Rhine, Seine, Loire, Danube)
• *5.2 Temporal identity (sense of rhythm)	• Traditional communities in the Danube Delta have historically organized their agriculture, fishing, and harvesting around the river's seasonal rhythms.
*5.3 Riverine soundscape and smell	Studies in Dutch lowland rivers show that river soundscapes vary predictably with physical characteristics such as depth, width, and water velocity, serving as navigational cues for migratory fish (Te Velde et al. 2024).
*5.4 Local climate (humidity and temperature of the air)	Cooling effect of urban rivers (Park et al. 2019; Wang et al. 2022), an example of a river mitigating the urban heat island in Sheffield, UK (Hathway and Sharples 2012)

Local and global changes causing bio-cultural co-decline in river floodplain systems

Today, synergies of industrialization, urbanization, and hierarchical social structures have collectively fostered an anthropocentric relationship with nature and a tacit acceptance of an unprecedented degradation of riverine ecosystems. Since 1970, freshwater biodiversity populations have declined by 85% globally—a rate exceeding all other species groups (WWF 2024), and nearly one-third of freshwater species are facing extinction (Albert et al. 2021). The 20th-century hydro-centric paradigm of water management, which primarily views rivers as resources or hazards (Hooper 2005), has led to management practices e.g., dam construction, resulting in severe ecological consequences, e.g., widespread habitat destruction – Europe's riverscapes are now the most fragmented globally, disrupted by over 1.2 million instream barriers (Belletti et al. 2020).

River-floodplains are social-ecological systems (Dunham et al. 2018) in which the degradation of ecological integrity directly corresponds with the erosion of associated cultural practices, a phenomenon termed bio-cultural co-decline or co-extinction (similar to "extinction of experience" (Soga and Gaston 2016)). This self-reinforcing cycle is manifested through empirical indicators. For instance, declines in fish populations often begin with the selective removal of larger individuals within a species, followed by the disappearance of larger species altogether, ultimately resulting in the collapse of previously diverse fish communities (Allan et al. 2005). Concurrently, indicators such as the progressive reduction in fishing net mesh sizes, increased catch-per-unit-effort performance, and the documented loss of culturally significant species that traditionally sustained local communities also highlight this phenomenon (Donahue and Johnston 1998). This bidirectional impairment demonstrates how biodiversity loss directly constrains nature's capacity to generate cultural values, resulting in interconnected declines of both, both ecological resilience and cultural heritage (Wantzen 2022).

Modern river management strategies that insufficiently capture the co-evolution of biodiversity and cultural diversity can fail to preserve either. When animal or plant populations fall below critical productivity or survival thresholds, tensions often emerge between biological and cultural conservation priorities. For instance, regulatory bans on fisheries targeting Allis shad or eel in the Loire River, have inadvertently disrupted longstanding traditional fishing, jeopardizing their cultural continuation (Wantzen et al. 2023a). On the other hand, cultural practices/products are often considered economically unviable due to reduced competitiveness in capitalist markets or risk disappearing entirely due to intergenerational cultural shifts (Wantzen 2022). For instance, increased commercialization, frequently accompanied by unsustainable exploitation, has greatly diminished the role of inland fisheries in Europe's protein supply. As a result, inland fishing has transitioned from an essential subsistence activity to a predominantly leisure pursuit, where primary satisfaction now is derived from the act of catching itself rather than from providing food for one's family—indeed, most captured fish are returned to the river (Arlinghaus et al. 2007).

Systematically, the bio-cultural co-decline in river-floodplain systems can be characterized as occurring in four phases (Wantzen 2022):

1. ***Loss of direct relationships*:** Direct interactions with riverine resources, e.g., traditional fishing methods or specific handicraft techniques like wattling, are lost.
2. ***Loss of indirect relationships*:** Cultural elements indirectly connected to river resources, e.g., poetry/music inspired by fishing, spiritual connections ("I am the river, the river is me", Te Aho 2019), and social norms/customs shaped by flood pulse, are disrupted or cease altogether.
3. ***Disconnection and replacement*:** Original objects and objectives traditionally associated with rivers are replaced by alternatives. During this phase, rivers lose their significance in community identity, a process accelerated by deteriorating water quality and negative perceptions associated with polluted waters (Wantzen et al. 2022b). This chemical degradation often goes along with a physical distancing – urban development canalising, undergrounding and crowding over rivers – so they are less visible in daily life.

4. ***Complete oblivion*:** Rivers and related hydrosystems entirely fade from public memory, especially when waterbodies have been physically altered or removed from the landscape, e.g., river burial/underground culverts (Wantzen et al. 2022a).

Cultural values as a driver for conservation, restoration and *de novo* creation of river floodplains

The bio-cultural co-decline described above highlights a need for integrated river management strategies that concurrently restore and enhance ecological integrity and cultural resilience. We argue that cultural practices in river-floodplain systems (as in Table 1) represent valuable tools for inspiring ecological restoration strategies and promoting wider ecosystem stewardship, fostering stronger kinship (Cohen et al. 2023) between humans and rivers (Chapin et al. 2010) and fundamentally transform human-river relationships in the Anthropocene. However, not all traditional cultural practices are compatible with the concepts of sustainability and conservation of socio-ecosystems, and need to be critically selected, revised and/or transformed (River Culture Tenet 3, Wantzen et al. 2016) Examples for such cultural practices can be provisionally classified into the following 4 categories:

1. Traditional cultural practices that are no longer in active use (e.g., due to the exploited species becoming rare or extinct) and cannot be directly revived in their original form. However, they may be adapted or repurposed to serve contemporary environmental management or educational objectives.

Examples of this include traditional fishing practices in rivers that no longer produce significant fish yields but can still offer valuable methods for monitoring fish populations. For instance, on the Loire River in France, professional fishermen historically provided precise data on the migration of eel (*Anguilla anguilla*) and Allis shad (*Alosa alosa*). However, due to the eel becoming commercially unviable and the withdrawal of modest financial support from watershed agencies, this valuable long-term dataset has been interrupted (Wantzen et al. 2023a). As a result, fish monitoring now requires more expensive sampling methods. A revival of the traditional fisheries with financial support for the service to monitor the populations of migratory fish could give this cultural practice a new significance.

Similarly, traditional boat-building techniques can no longer compete commercially with modern shipping methods, or rivers previously used for navigation may no longer be navigable. For example, the “batellerie de la Loire,” historically significant for transporting salt upstream from the sea to Orléans, has ceased its original function (Wantzen et al. 2023a). Nonetheless, traditional boat architecture has found renewed purpose in tourism and public outreach. The “Grande remontée,” a biennial event featuring up to 100 traditional boats, exemplifies this revival by promoting awareness and advocating for granting juridical personhood to the Loire River (Cao et al. in press). Ancient river mills represent another example. In Minden, Germany, and old mill ship mill has been renovated to showcase the potential of renewable energy, thus connecting historical heritage with contemporary sustainability efforts (https://www.schiffmuehle.de/). This practice has to be considered with care in the context of biodiversity conservation. While in ship mills the wheel is hung

into the river without adding barriers (but slowing down the flow), historic mill restoration (with weirs) involves new barriers to fish migration. For example, water mills in the Rhine tributaries already reduced salmon populations during the late Middle Ages (Lenders et al. 2016).

2. Traditional cultural practices no longer in use and incompatible with biodiversity conservation (but valuable as anecdotal references for historical human-river relationships)

Certain traditional river-based cultural practices, while historically significant, are no longer compatible with contemporary sustainable development goals. For instance, wood rafting on the Rhine River, if re-established today, would severely disrupt modern intensive navigation. Nevertheless, wood rafting is still demonstrated in valleys of select tributaries through open-air living museums (Freilandmuseen), serving as a cultural reminder of historical practices that once connected distant communities along rivers (examples in Wantzen et al. 2023b).

Similarly, the traditional flooding of meadows in tributary valleys of the Black Forest and Vosges mountains, historically employed for agricultural productivity and biodiversity, has ceased due to changing land use and modern agricultural practices (Leibundgut 1993). In the context of climate change adaptation, however, this technique is currently being discussed to see if could be revitalized.

Another example of obsolete cultural practices is the historical construction/use of small, low-head dams and weirs in Europe (Belletti et al. 2020). Today, these instream barriers pose significant hazards due to powerful recirculating currents, known as "drowning machines," obstruct the migration routes of aquatic species and threaten native fish biodiversity (Smith et al. 2017). Recognizing these risks and ecological consequences, the European dam removal movement has dismantled 487 barriers across 15 countries in 2023 alone, reconnecting over 4,300 kilometers of rivers (Mouchlianitis 2024). This restoration effort has contributed to biodiversity recovery, habitat restoration and climate resilience for both human and beyond-humans (Stoffers et al. 2024). Furthermore, the EU's recent adoption of the Nature Restoration Law (Hering et al. 2023) reinforces these efforts, setting ambitious targets of restoring 25,000 kilometers of free-flowing rivers in Europe by 2030.

3. Traditional cultural practices, still in use but currently diminished, can be maintained or potentially revived in their original form

River bathing and swimming have a long history, dating back to the fitness-oriented practices of ancient Greeks and Romans, later evolving into dedicated riverfront hygiene facilities (Chaline 2018). In ancient times, swimming/bathing in natural rivers were also appreciated for their recreational and therapeutic benefits, as advocated by (Thévenot 1699) (France) and (Sir John Floyer (1649–1734) 1943) (UK). In the 19th century, gender-segregated floating bathhouses became popular features of European rivers, exemplified by Lyon's "Bains de la Tête d'Or" (Terret 1994), which was operated by the municipality to improve public hygiene (especially for the working class). However, due to industrialization and urbanization, the 20th century witnessed a dramatic decline in river bathing, with widespread river channelization, increased water

pollution, and severe ecological degradation that rendered many European waterways unsuitable for human physical contact (Brookes 1989). At the same time, growing concerns about safety and conflicts with navigation prompted the implementation of bathing bans in major European cities—many of which remain in effect today (Maghakian et al. 2024; Cao et al. 2025b) (and see Fig. 3).

Since the 1980s, EU environmental legislation—particularly the Water Framework Directive (2000/60/EC) and Bathing Water Directives (76/160/EEC; revised 2006)—has driven significant improvements in river water quality in most European countries. By 2023, 85% of Europe's 22,081 monitored bathing sites achieved "excellent" quality standards (EEA 2024). Amid rising summer temperatures and increasing public demand for outdoor recreation, interest in reopening urban rivers for swimming/bathing has surged considerably in Europe. In Paris, where bathing in the Seine had been prohibited since 1925, authorities have invested over €1.4 billion since 2015 to restore water quality to safe swimming standards (Mouchel et al. 2021). During the 2024 Olympics, despite some difficulties and after an enormous (and publicly debated) effort to improve the water quality (Cao et al. 2025b), the Seine River successfully hosted six Olympic swimming events, and public bathing is scheduled to resume in 2025. Concurrently, grassroots initiatives such as the global Swimmable Cities Alliance (https://www.swimmablecities.org/) or Drinkable Rivers (https://drinkablerivers.org/) are actively working to revitalize the once-prominent cultural tradition of urban river swimming/bathing and make urban rivers accessible, inclusive public spaces again.

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BAIGNADE INTERDITE
VEILLEZ SUR VOS AMI·ES

Figure 3. Bathing is forbidden in the River Ill in Strasbourg. Photo: Cao.

4. Newly developed/adapted cultural practices, of which the sustainability aspect is prioritized

Recreational activities, e.g., motor boating, kayaking, paddleboarding, and leisure fishing can support sustainable management and conservation goals when they effectively motivate participants to engage in nature protection initiatives. Supported by UNESCO's global network of Water Museums WAMU-NET (https://www.watermuseums.net/), some river museums in Europe have evolved into educational and scientific centers – for example, the Ecomuseum of Rice Fields in Castel d'Ario (Mantua), Italy is dedicated to exploring the interactions between rice cultivation and riverine landscapes in the Po Valley and hosts traditional festivals/events that celebrate local cuisine.

However, newly developed cultural (mostly recreational) activities may also negatively impact biodiversity. In the Loire river basin, kayak landings on sandbanks or gravel bars during the breeding season of ground-nesting birds, e.g., plovers and terns, can severely disrupt reproduction, leading to a loss in offspring survival (Yousry et al. 2022). Similarly, recreational bathing and wading in the Isar River, Munich, have markedly reduced suitable habitats for the nase (*Chondrostoma nasus*), a key target species for ecological restoration efforts (Zingraff-Hamed et al. 2018). To address these challenges, detailed analyses of species-specific ecological requirements and careful urban planning are needed, e.g., guiding recreational activities toward less sensitive areas and/or creating buffer zones to mitigate negative ecological impacts. The city of Geneva targeted a balanced approach by simultaneously promoting habitat restoration and recreational activities: compensatory reedbed habitats have been established on the upstream of new bathing sites at Plage des Eaux-Vives (opened in 2020) and Cologny Quay (opened in 2024) on Lake Geneva (Cao et al. 2025a).

Conclusion

In this paper, we have revealed the rich diversity of river floodplain systems while highlighting a concerning trajectory of co-decline of biological and cultural traits in Europe. Integrating traditional and modern knowledge systems with adaptive strategies—rooted in the inherent cultural connectivity of river ecosystems—offers a promising pathway to enhance river ecological conservation and management. To facilitate practical applications, we categorize these cultural practices into four distinct groups: (1) inactive practices adaptable for modern use; (2) discontinued practices valuable only historically; (3) diminished yet revivable traditional practices; and (4) newly developed or adapted practices emphasizing sustainability.

Moving forward, priority should be given to practical, evidence-based approaches that include rigorous cost-benefit analyses and detailed examinations of implementation barriers. For example, the Eurometropole Strasbourg is currently planning an intra-urban, multi-purpose park along an ancient floodplain channel of the Rhine (Krimmeri, Rhin Tortu), which will combine the concepts of human-river-encounter sites (Zingraff-Hamed et al. 2021) with stream restoration, flood-retention zoning, creation of a "thermal refuge" for the human population during heat waves. A multi-sectorial communication strategy will be elaborated to contact and motivate very different types of stakeholders to participate in the diverse conservation activities.

Documenting the strategies that successfully overcome these obstacles is equally important. To ensure the sustainability of these efforts, we advocate the establishment, maintenance, and regular evaluation of standardized, publicly accessible databases that document successful practices in European riverscapes. A critical revision of the existing databases shows that they are often incomplete, e.g., when it comes to urban river restoration (Zingraff-Hamed et al. 2017) and success of restoration or NbS (Jähnig et al. 2011). A database combining ecosystem types, "classical" environmental problems and engineering/communication techniques to introduce adequate solutions sustainably into society are, to our knowledge, currently missing. Such knowledge repositories could facilitate cross-regional learning and support the replication of effective biocultural conservation initiatives. By bridging cultural heritage with ecological stewardship, we can foster resilient river-floodplain systems that sustain both biodiversity and river culture.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

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Data availability

All of the data that support the findings of this study are available in the main text.

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